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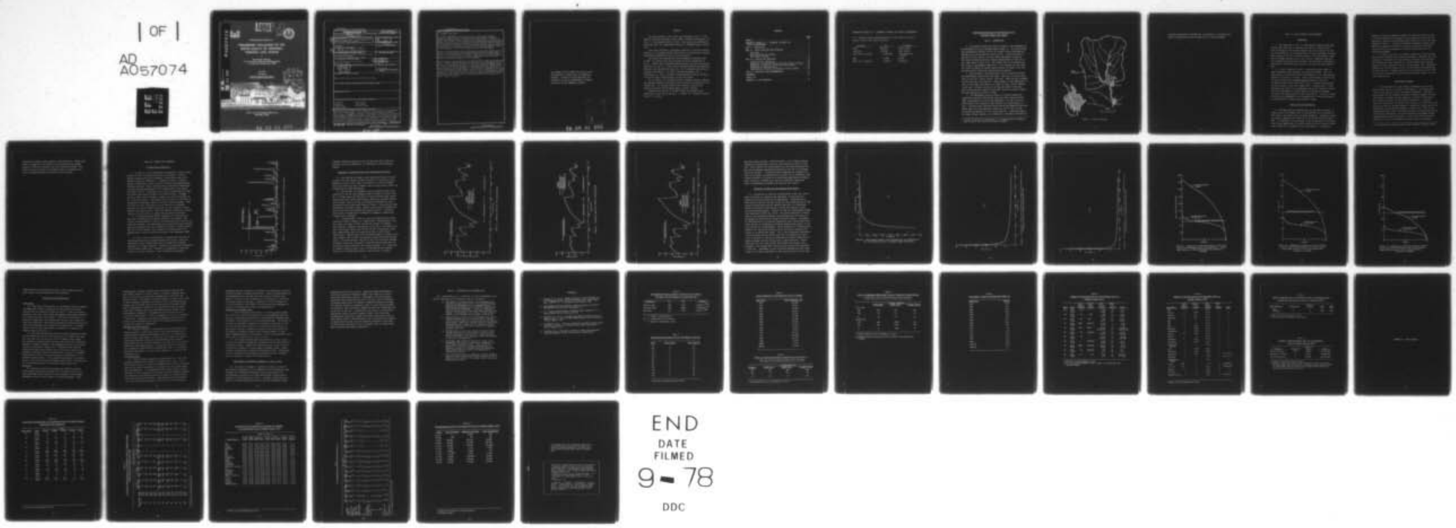

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PRELIMINARY EVALUATION OF THE WATER QUALITY OF PROPOSED TOWANDA LAKE, KANSAS

by

Environmental Laboratory
U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

June 1978

Final Report

Approved For Public Release; Distribution Unlimited

Prepared for U. S. Army Engineer District, Tulsa
Tulsa, Okla. 74102

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The proposed Towanda Lake would be formed by the impoundment of the Whitewater River near Towanda, Kansas. Project purposes would include flood control, water supply, and general recreation. The purpose of this study was to investigate possible water-quality problems that may affect the realization of project benefits—particularly the effects of total dissolved solids (TDS), chloride, and sulfate concentrations on water supply suitability. Because of the high concentrations of these parameters, possible treatment processes were to be evaluated for alleviation of potential water supply problems. (Continued)

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20. ABSTRACT (Continued).

The proposed impoundment would probably be well mixed, exhibiting weak, ephemeral stratification only during periods of calm weather. Therefore, a mass-balance routing of TDS, sulfates, and chlorides through the pool was performed. Daily values of these parameters were generated from continuous specific conductance data and used in conjunction with daily discharge data for input to the routing model. Additionally, data were obtained on trace metals, pesticides, and nutrients for a preliminary evaluation of the possible detrimental effects of these substances on the overall water quality for the impoundment.

Results of the mass-balance routing indicated that only minor problems should be expected with TDS levels and that chloride and sulfate levels should remain below U. S. Environmental Protection Agency (EPA) criteria for these parameters. On the basis of this analysis, no special considerations in water treatment design are considered necessary for these parameters.

Concentrations of mercury and phenol exceeded acceptable levels in the Whitewater River. Although concentrations of these substances in the impoundment are expected to be less than those measured in the river, additional sampling should be conducted to determine the degree of contamination and the expected fate of these constituents in the impoundment. Occasional algal blooms should be expected during periods of calm weather and this should be considered in the design of the water supply withdrawal system. Levels of fecal coliform bacteria in the headwaters of the reservoir should be expected to exceed EPA criteria following storm events, and this may preclude the use of portions of the reservoir for primary contact recreation.

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PREFACE

The work described in this report was performed by the U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Mississippi, for the U. S. Army Engineer District, Tulsa. The project was authorized by Intra-Army Order for Reimbursable Services No. TOF770009 dated 15 March 1977.

This report describes a preliminary evaluation of the water quality expected in the proposed Towanda Lake relative to water-quality criteria and standards appropriate for the project purposes.

The project was undertaken by the Environmental Laboratory (EL) at WES. The research was conducted under the direct supervision of Mr. D. L. Robey, Chief, Ecosystem Modeling Branch, and under the general supervision of Drs. R. L. Eley, Chief, Ecosystem Research and Simulation Division, and John Harrison, Chief, EL. Mr. R. Michael Smart served as principal investigator. Dr. Kent W. Thornton and Messrs. N. R. Francingues, Jr., Chief, Treatment Processes Research Branch, and Ross W. Hall provided a detailed review of the draft report.

Mr. Cal Albert, U.S. Geological Survey, Lawrence, Kansas, conducted the sampling program and provided the water-quality data obtained at the Towanda Gage. Mr. Charles Cochran, Tulsa District, conducted the regression analysis and the mass-balance reservoir routing.

Commander and Director of the WES during the preparation and publication of this report was COL J. L. Cannon, CE. Technical Director was Mr. F. R. Brown.

CONTENTS

CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
acres	4046.856	square metres
acre-feet	1233.482	cubic metres
cubic feet per second	0.02831685	cubic metres per second
feet	0.3048	metres
miles (U. S. statute)	1.609344	kilometres

PRELIMINARY EVALUATION OF THE WATER QUALITY OF PROPOSED TOWANDA LAKE, KANSAS

PART I: INTRODUCTION

1. The proposed Towanda Lake would be formed by the impoundment of the Whitewater River near Towanda, Kansas (Figure 1). The project would have approximately 200,000 acre-ft* of storage of which approximately 130,000 acre-ft is allocated for flood control. Project purposes, in addition to flood control, are water supply and general recreation. The reservoir would be shallow, having a maximum depth of about 45 ft and a mean depth of about 12 ft. The surface area of the conservation pool would be approximately 6000 acres. It is expected that the reservoir would be similar in thermal characteristics to others in the area and would thus be weakly and intermittently stratified.

2. The watershed is characterized by very low population density and predominantly agricultural land usage. There are only three small towns in the area: Potwin, Benton, and Furley. Wheat and grain sorghum are the principal crops produced. Cattle grazing is also significant in terms of land usage, and there are a number of small, private feedlots in the area. Although drilling in the area was common in the past, these operations have ceased; and the small refinery at Potwin, Kansas, has been inoperable for about a decade.

3. The impoundment would be located in a natural gypsum area resulting in naturally high sulfate (SO_4) and total dissolved solids (TDS) concentrations in runoff and groundwater. The use of brine for extracting oil has resulted in high chloride (Cl) concentrations as well. The Kansas Water Resources Board and the Environmental Protection Agency (EPA) have thus expressed concern over the Cl, SO_4, and TDS concentrations expected to occur in the reservoir. Since water supply is a major project purpose, it is imperative to determine the degree of

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* A table of factors for converting U. S. customary units of measurement to metric (SI) units can be found on page 3.

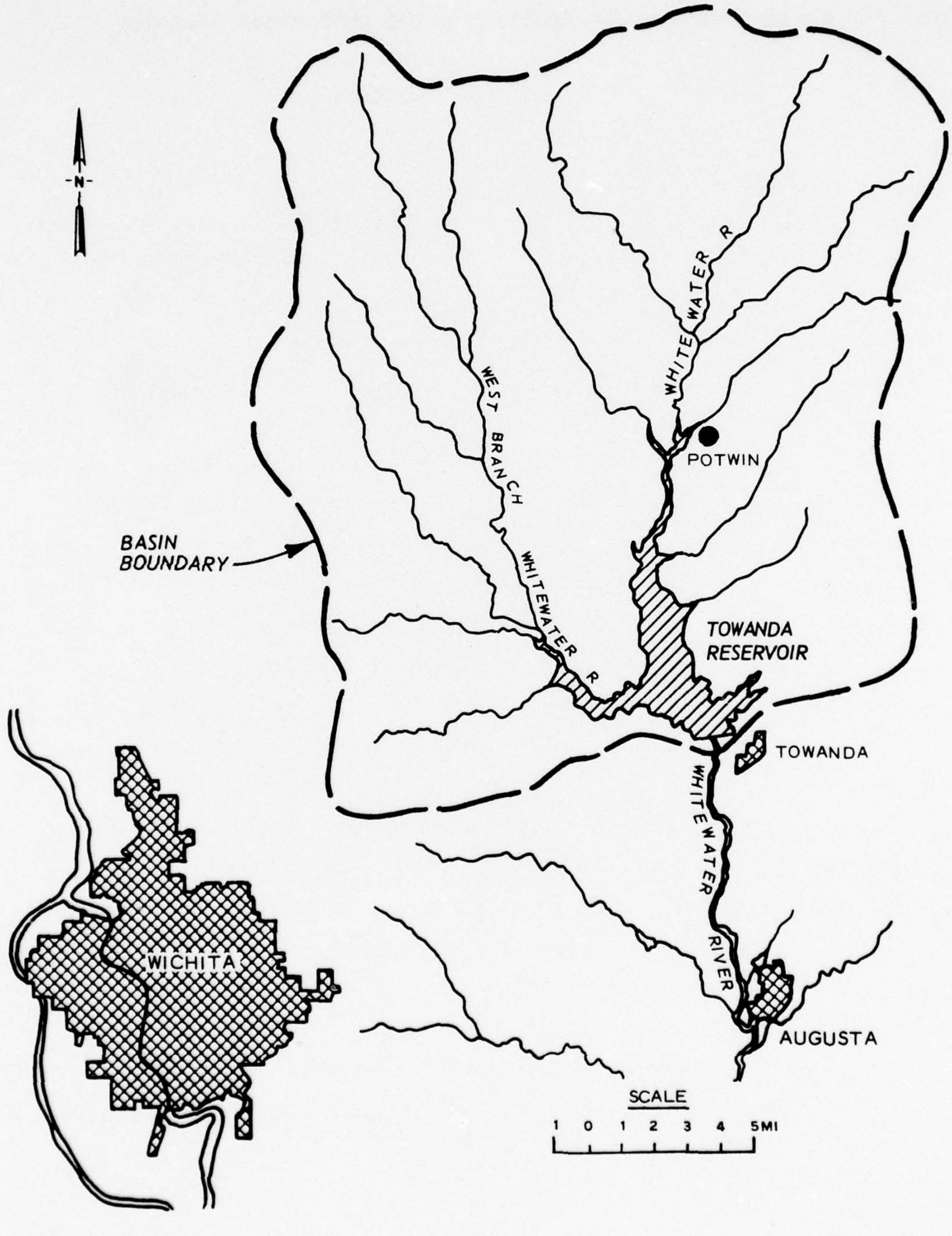

Figure 1. Project area map

potential water-quality problems and, if necessary, to evaluate procedures for dealing with these problems prior to further planning.

PART II: STUDY OBJECTIVES AND PROCEDURES

Objectives

4. The objectives of the U. S. Army Engineer Waterways Experiment Station (WES) study were to determine the extent of expected water-quality problems in the proposed Towanda Lake and to evaluate the need for, and feasibility of, associated water treatment necessary to provide water supply for the city of Wichita, Kansas. The water-quality parameters of primary concern were Cl, SO_4, and TDS. Additional data were also obtained on heavy metals, nutrients, and pesticides to provide an indication of the overall water quality to be expected in the impoundment.

5. A study conducted by the U. S. Geological Survey (USGS) in 1969[1] indicated serious potential water-quality problems. They concluded that total dissolved solids concentrations in the river exceeded 1000 mg/ℓ 70 percent of the time. River concentrations of sulfates and chlorides exceeded their maximum permissible levels of 250 mg/ℓ for domestic water supply (raw water)[2] and for finished drinking water[3] 79 and 32 percent of the time, respectively. Concentrations of these substances are likely to be considerably less in the reservoir, however, due to the impoundment of large volumes of storm flows containing relatively low concentrations of these constituents. In order to assess the effects of impoundment on the concentrations of these constituents, it was necessary to perform a mass-balance routing.

Data Collection and Analysis

6. Although USGS had determined SO_4, Cl, and TDS on a monthly to weekly basis at the Towanda Gage, it was desirable for the purposes of this study to have daily values of these parameters. Continuous records of specific conductance were obtained at the Towanda Gage from 1964 to 1969. As conductance is proportional to the concentration of dissolved salts, these numbers give a reliable indication of the relative fluctuations of each of the parameters under investigation. A regression

analysis of specific conductance values with concurrent values for SO_4, Cl, and TDS indicated a high degree of correlation and resulted in the selection of equations for generating daily values for each of the three parameters (Table 1). Continuous discharge measurements obtained from 1962 to the present by the USGS were used in conjunction with daily values for the above parameters to calculate mass balances for the proposed impoundment.

7. In order to provide a preliminary indication of other possible water-quality problems in the proposed impoundment, additional data were obtained on concentrations of heavy metals, nutrients, and pesticides in the Whitewater River (Appendix A). Monthly samples were obtained during base flow conditions from April through August 1977. Additional samples were obtained during each of two storm events occurring during the study period. A sediment sample was also obtained in May 1977 from a pool at the Towanda Gage and was characterized with respect to pesticide concentrations.

Mass-Balance Routing

8. The assumption that the proposed impoundment would be well mixed allowed the use of a simple routing model for calculating daily values in the lake for each of the chemical parameters. This model incorporated inflows; assumed instantaneous mixing throughout the pool; and allowed for changes in pool volume due to rainfall, evaporation, water-quality releases, and water supply withdrawals. During the initial filling period, no releases occurred until the conservation pool elevation (1285 ft)* had been reached. Conservation storage used in the mass-balance routing was approximately 74,500 acre-ft. When the pool elevation was above 1285 ft, releases were equal to inflows plus precipitation minus evaporation. Below this elevation the minimum release schedule shown in Table 2 was used. In the event the pool elevation decreased to 1275 ft, water-quality releases would be terminated.

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* All elevations cited herein are in feet referred to mean sea level.

Conservation storage at this elevation is 28,500 acre-ft. During storm events, releases were not allowed to exceed the downstream channel capacity of 5000 cfs; therefore, the pool elevation increased. This flood storage was released at the maximum amount on subsequent days until the conservation pool elevation was again attained.

PART III: RESULTS AND DISCUSSION

Setting Initial Conditions

9. In order to run the mass-balance routing model, initial concentrations of each of the parameters must be established. As these initial concentrations affect subsequent concentrations, the use of realistic values was imperative. To examine the effect of various initial concentrations, initial filling of the pool was simulated under different conditions. These conditions were selected after examination of annual discharge measurements at the Towanda Gage for the period 1962-1976 (Table 3). Conditions were selected to approximate the range of probable conditions that might occur during filling: a drought period of about 10-year frequency, a median year, and a storm event of 10- to 20-year frequency. The median year was selected on the basis of seasonality of discharge (Figure 2) as well as annual discharge. Water Year (WY) 1967 (the true median) was rejected due to the unusual occurrence of drought conditions early in the year followed by storm events in the latter portion. Water Year 1968 was selected as a median year due to the occurrence of normal seasonal peaks in discharge.

10. Filling was accomplished by impounding all inflowing water until the conservation pool elevation (1285 ft) was attained. This process took approximately 1 year for the median year and 6 days for the storm event filling. The conservation pool elevation was never attained during the drought period due to insufficient inflow. Concentrations of TDS, SO_4, and Cl achieved in this manner are representative of the maximum range of initial conditions expected in the impoundment (Table 4).

11. Table 5 shows the convergence of concentrations for each of the parameters during two subsequent median-year cycles. After two median-year cycles, concentrations were not appreciably different regardless of filling conditions. Therefore, concentrations attained by filling during a median year followed by two median-year cycles were selected as initial conditions. These concentrations represent

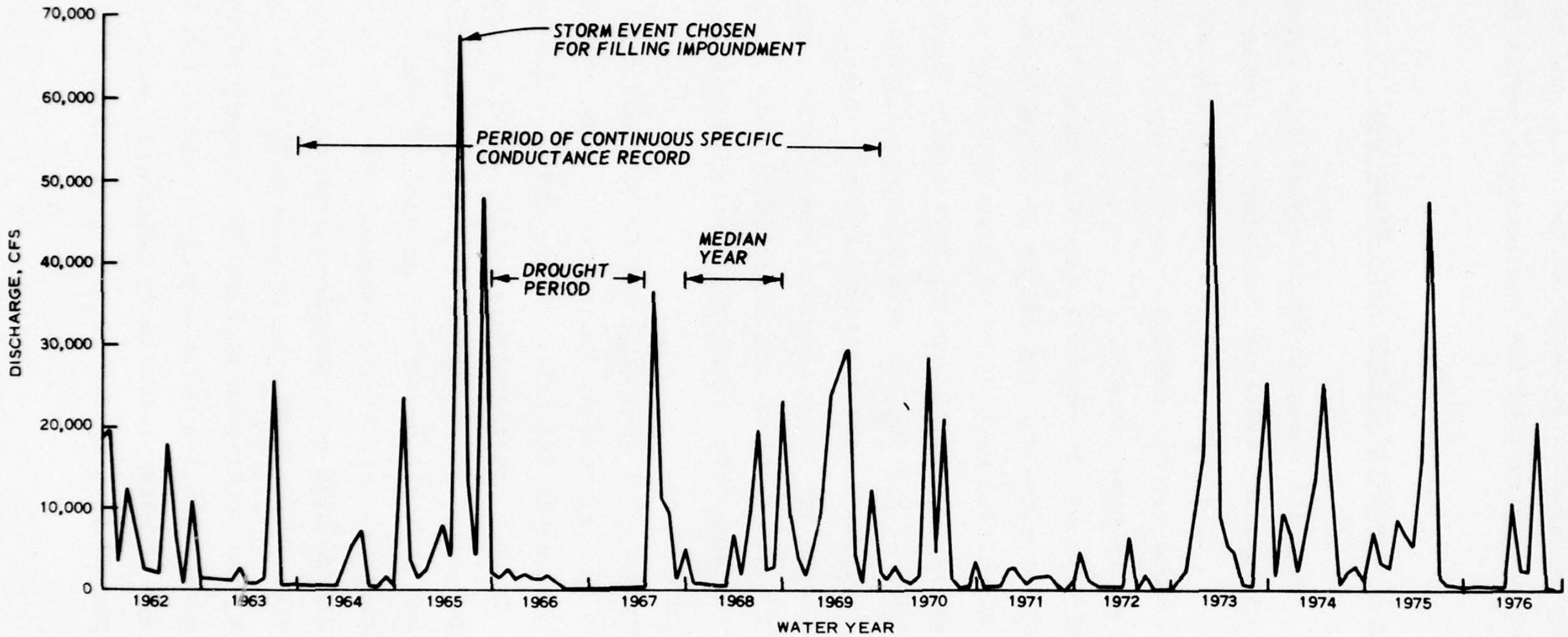

Figure 2. Discharge record for the Whitewater River at Towanda, Kansas

"average" conditions expected to occur in the pool, and as such, are realistic initial concentrations for simulating a 6-year hydrologic routing.

Comparison of Predicted Values with Water-Quality Criteria

12. EPA criteria for domestic water supply (raw water) are incorporated in the EPA "Quality Criteria for Water."[2] Criteria for those substances listed in this report are identical for raw and finished waters as conventional water treatment does not significantly affect the concentration of these constituents.

13. The EPA does not recommend a specific domestic water supply criterion for TDS but cites maximum values of 250 mg/ℓ for both Cl and SO_4.[2] Problems associated with water of high dissolved solids content include unpleasant tastes, physiological (especially laxative) effects, and corrosion. Both Cl and SO_4 are primarily responsible for taste problems while SO_4 alone causes laxative effects. Concentrations below the 200-mg/ℓ criterion for these elements should afford reasonable protection from both taste problems and laxative effects.[2] The Public Health Service "Drinking Water Standards"[3] recommends a maximum TDS concentration of 500 mg/ℓ.

14. Concentrations of TDS, SO_4, and Cl obtained from the 6-year routing are shown in Figures 3-5, respectively. Concentrations of SO_4 were always well below the EPA criterion of 250 mg/ℓ for domestic water supplies. Maximum concentrations of SO_4 and Cl, occurring at the end of the drought period, were 190 and 125 mg/ℓ, respectively, while mean concentrations over the 6-year period were 131 and 74 mg/ℓ, respectively. Concentrations of TDS exceeded 500 mg/ℓ 37 percent of the time, primarily due to high concentrations achieved during the drought period. As concentrations of SO_4 and Cl were well below their maximum acceptable values, the occurrence of high TDS concentrations does not necessarily indicate potential water supply problems. In a study based on consumer surveys of water taste in 29 California water systems, Bruvold et al.[4] showed that waters of less than 659 to 755 mg/ℓ

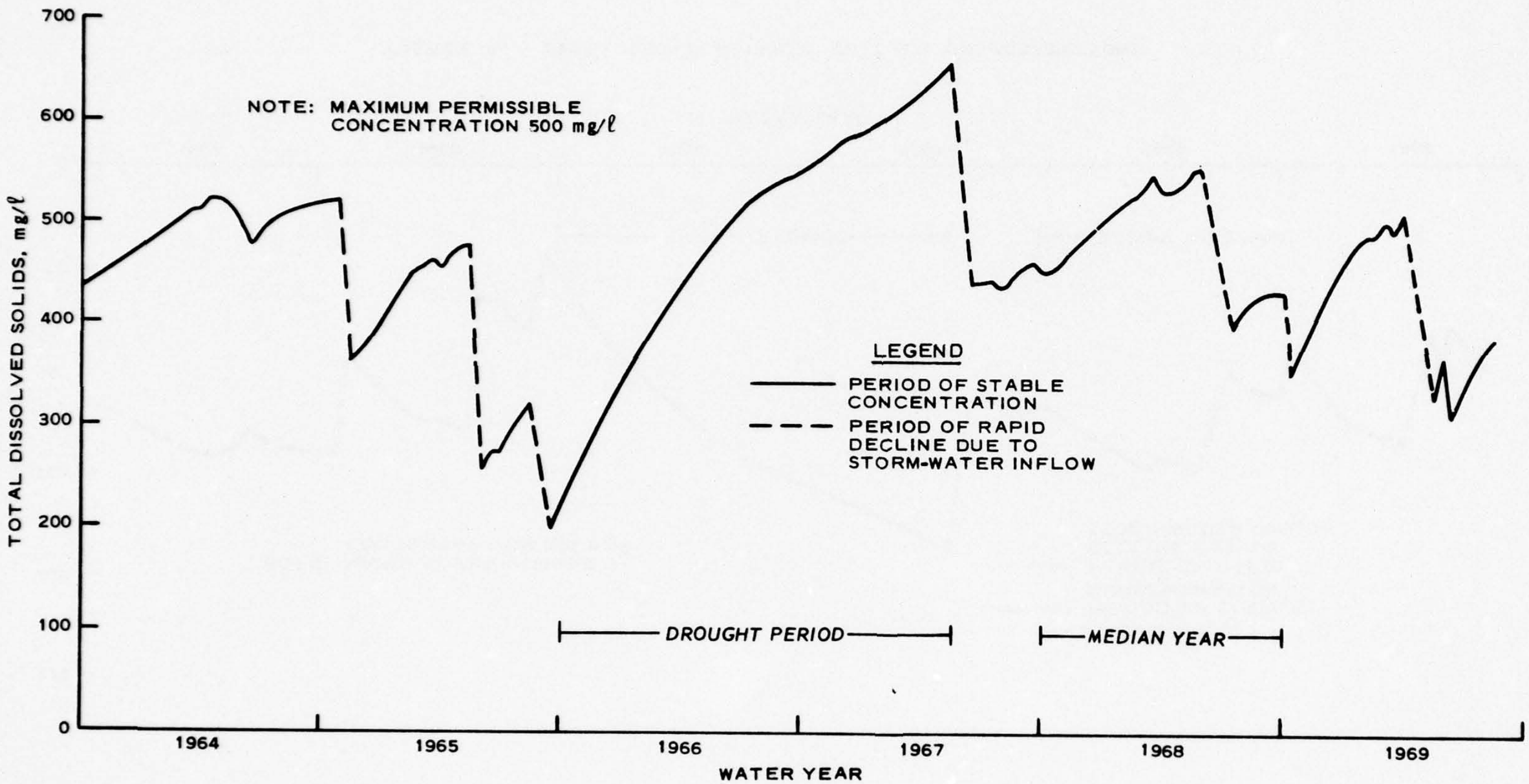

Figure 3. Predicted reservoir TDS concentrations

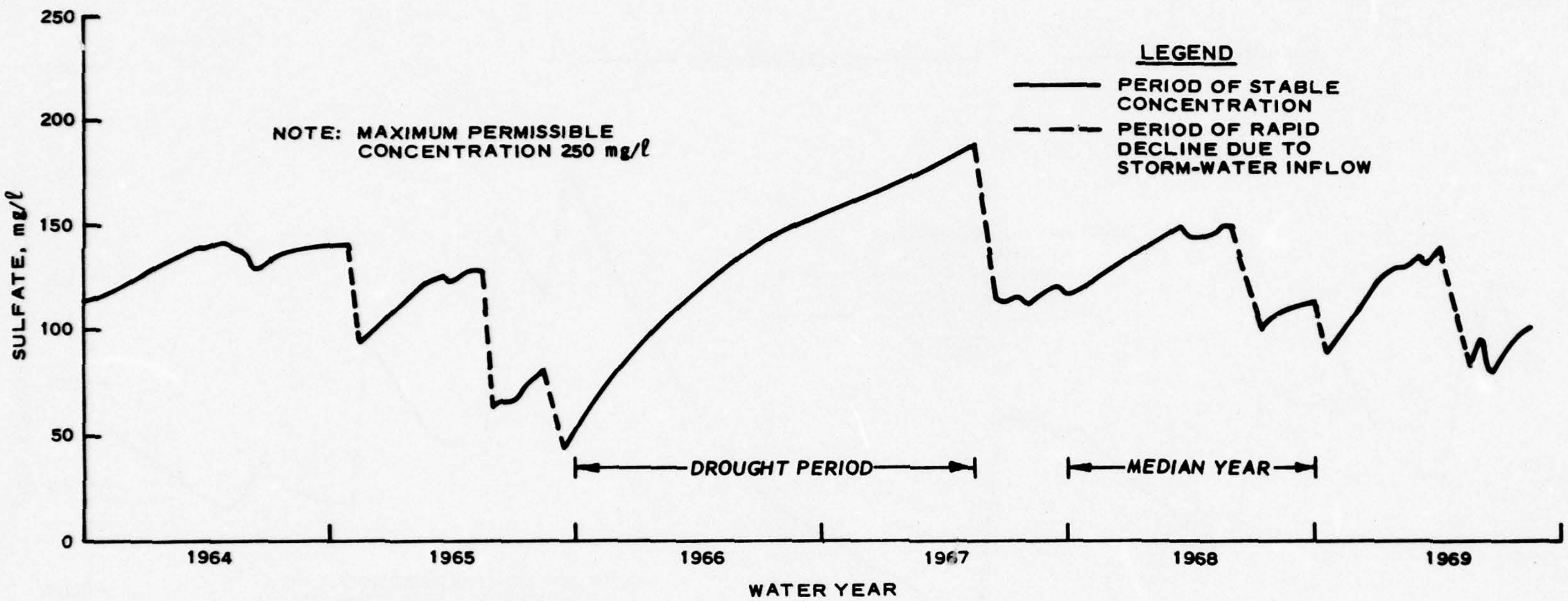

Figure 4. Predicted reservoir sulfate concentrations

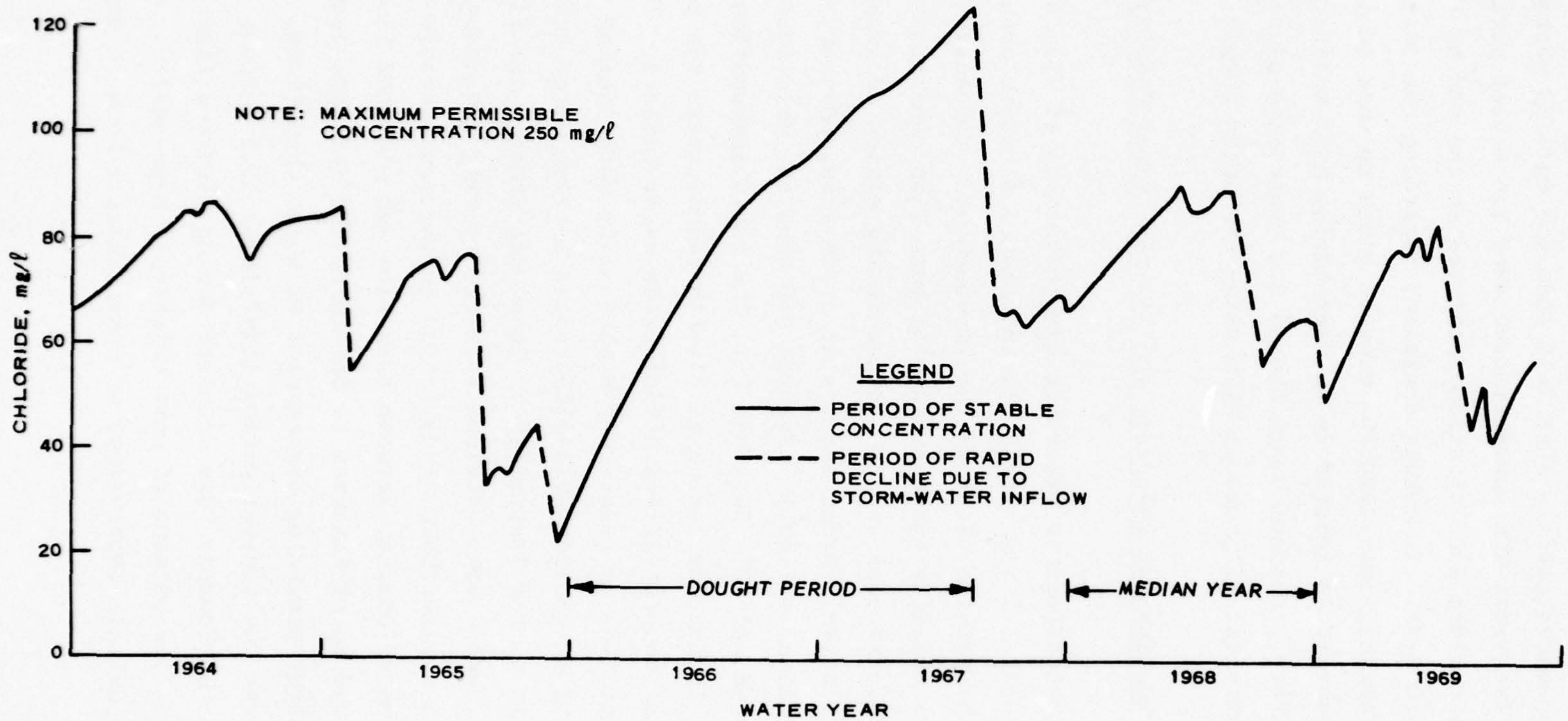

Figure 5. Predicted reservoir chloride concentrations

dissolved solids received a rating of "good." In the 6-year reservoir routing, TDS concentrations were less than 658 mg/ℓ 99 percent of the time. Mean reservoir TDS concentration over the 6-year period was 462 mg/ℓ and the maximum concentration predicted at the end of the drought period was 660 mg/ℓ. In making decisions regarding the suitability of water for drinking, consideration must be given to user acclimation. The proposed reservoir is located in an area having high-salinity drinking water; therefore, resident users should not experience significant taste or physiological problems from using the water supply.

Comparison of Reservoir and Riverine Water Quality

15. Fluctuations in reservoir concentrations of TDS, SO_4, and Cl shown in Figures 3-5 illustrate the importance of storm events in regulating the water quality of the impoundment. Concentrations of these species steadily increased during base flow conditions due to high influent concentrations and the concentrating effect of evaporation. During the relatively brief periods of storm flow, however, concentrations decreased markedly. Figures 6-8 show the relationships between river discharge and TDS, SO_4, and Cl. The rapid attenuation of concentration with increasing discharge clearly demonstrates the reason for declining pool concentrations during storm-water inflows. Impoundment of large quantities of relatively high-quality water during these storm events results in considerable differences between water quality of the river and that of the impoundment. These differences are illustrated in Figures 9-11, where data obtained from the routing are compared with results of an earlier USGS study.[1] Due to the considerable differences in riverine water quality between base flow and elevated flow conditions, it would be of interest to determine the relative quantities of annual discharge occurring during each of these conditions. Table 6 shows that over the 15-year period (1962-1976) 55.3 percent of the discharge at the Towanda Gage occurred during elevated flow conditions (> 2000 cfs). Impoundment of this relatively high-quality water would result in an overall improvement of water quality both in the pool and

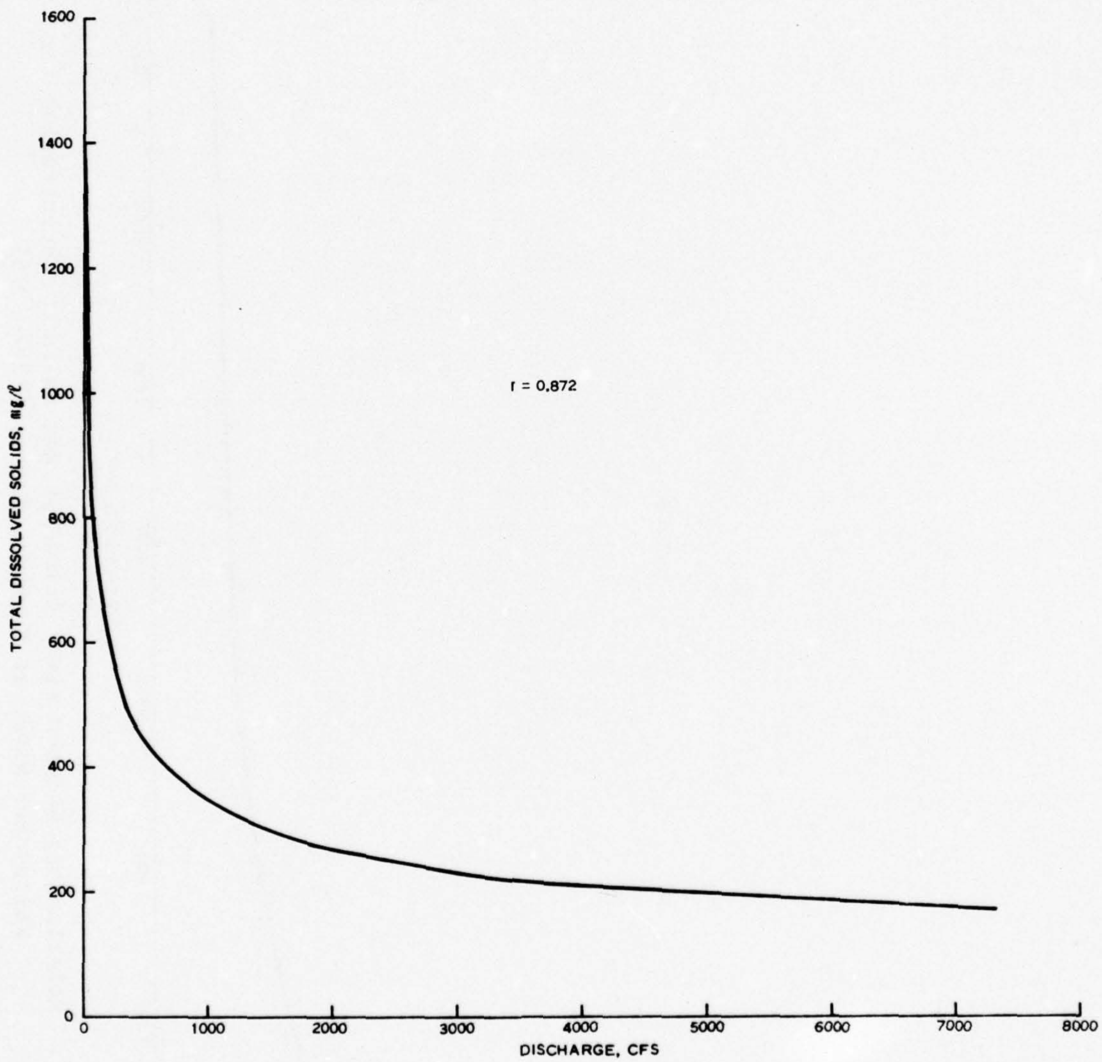

Figure 6. Relationship between river discharge and TDS concentration for the Whitewater River at Towanda, Kansas (1962-1975)

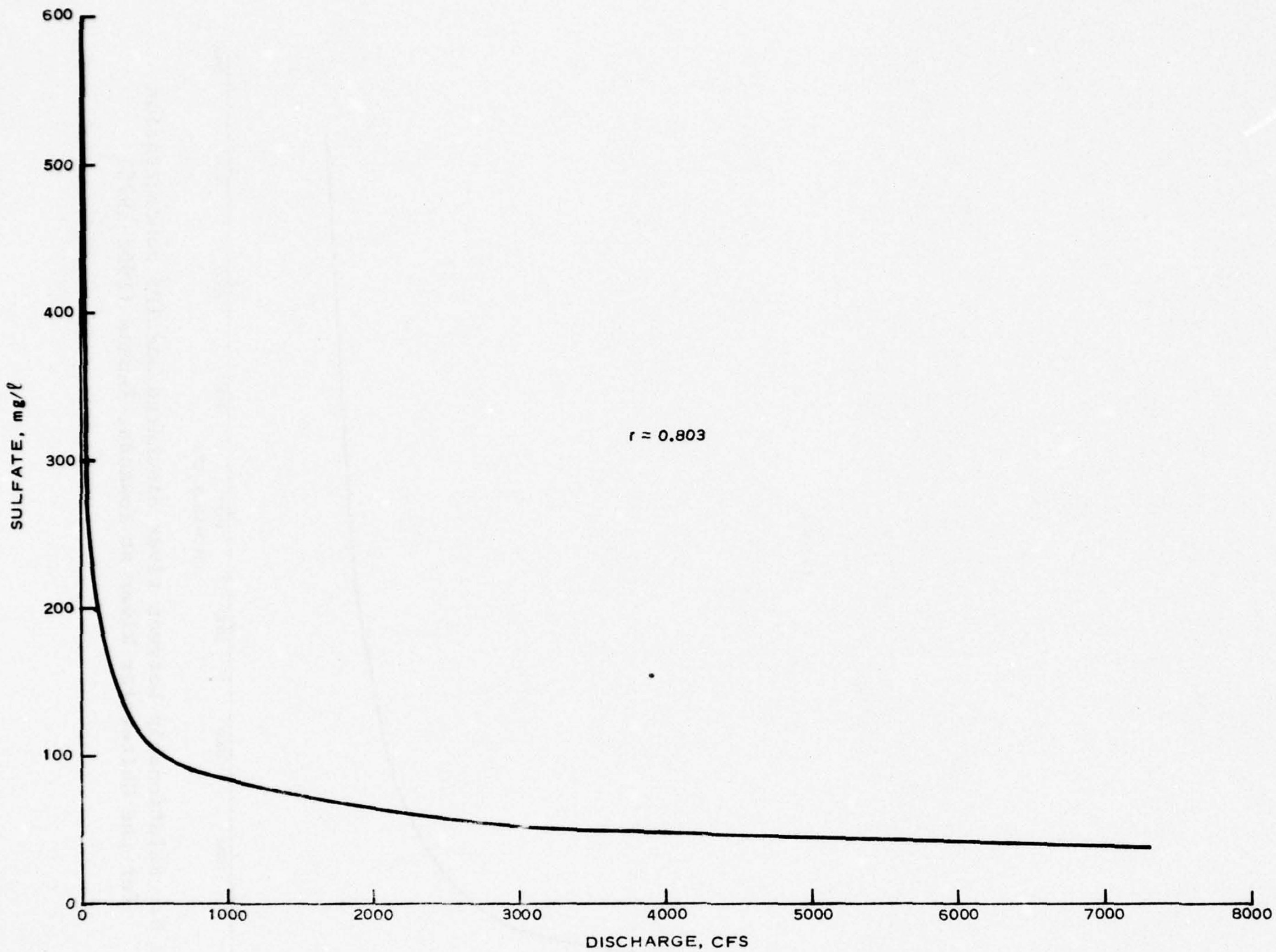

Figure 7. Relationship between river discharge and sulfate concentration for the Whitewater River at Towanda, Kansas (1962-1975)

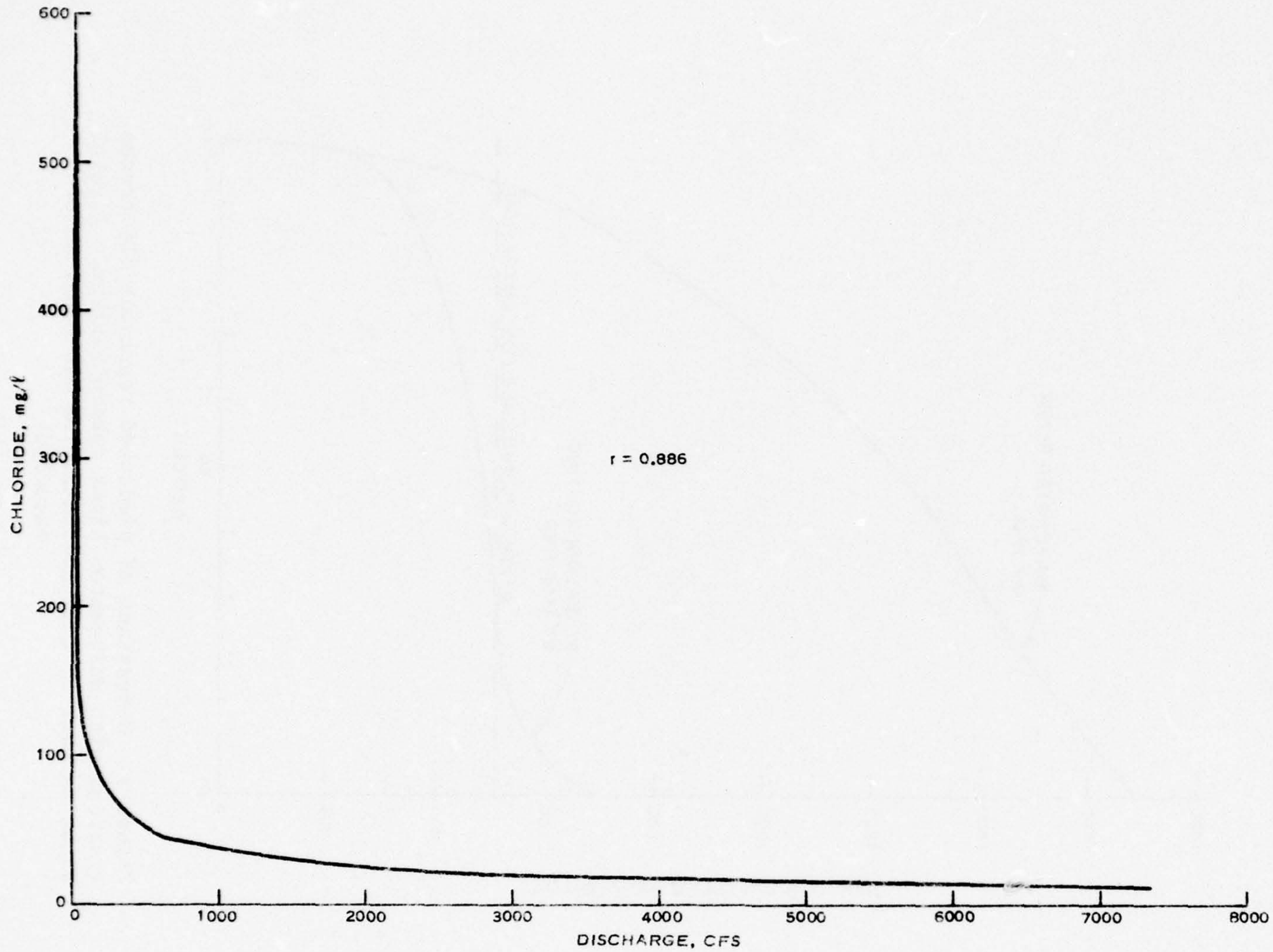

Figure 8. Relationship between river discharge and chloride concentration for the Whitewater River at Towanda, Kansas (1962-1975)

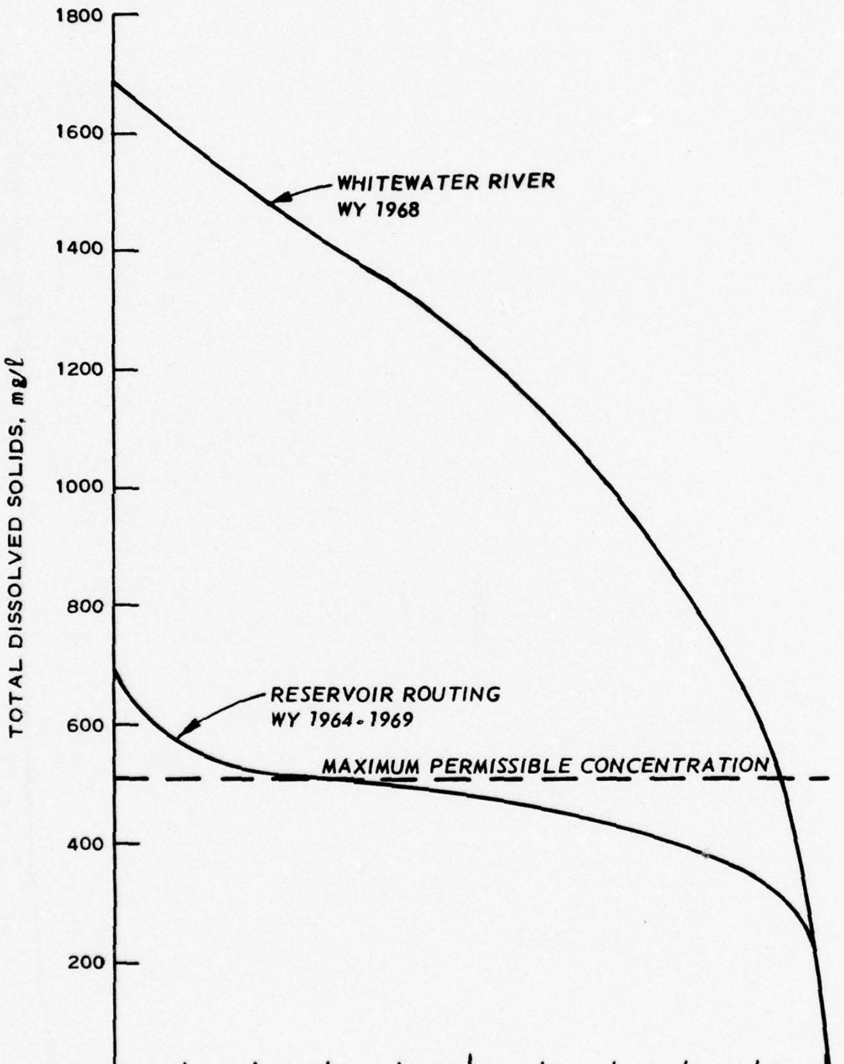

Figure 9. Comparison of predicted reservoir TDS concentrations with Whitewater River concentrations. Figure shows percent of time concentration was equalled or exceeded

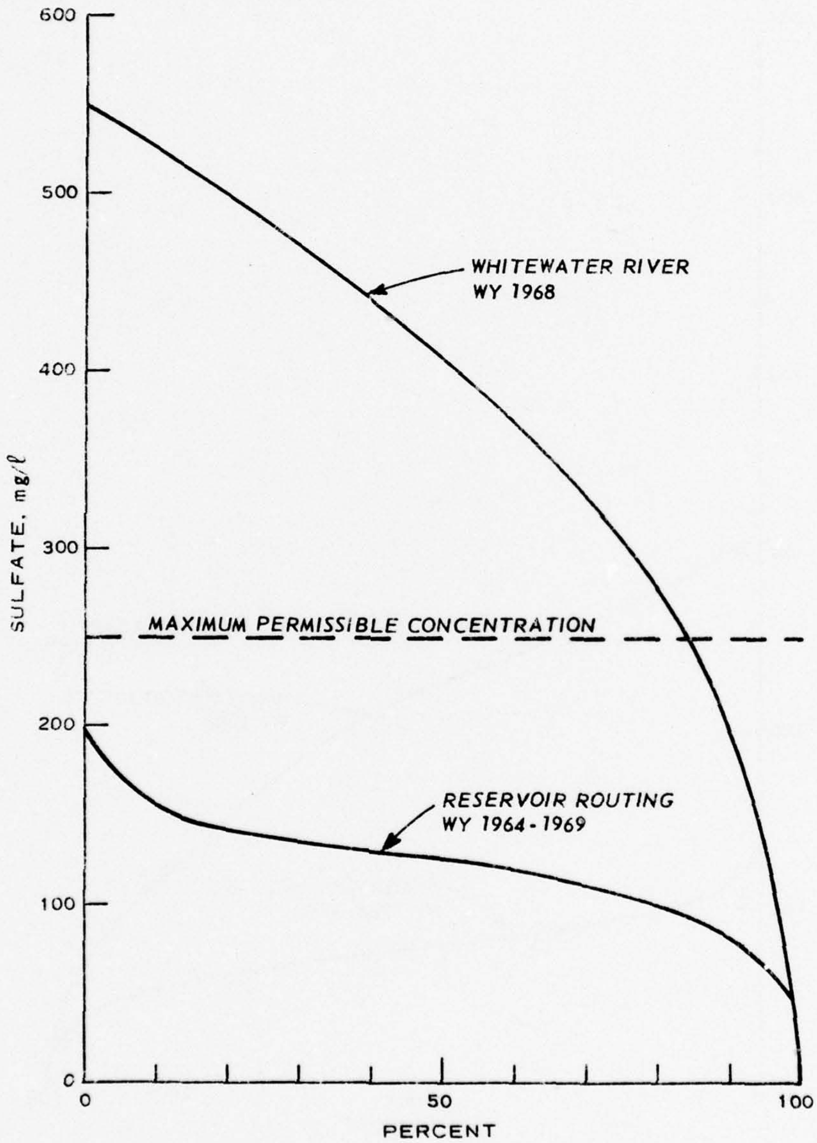

Figure 10. Comparison of predicted reservoir sulfate concentrations with Whitewater River concentrations. Figure shows percent of time concentration was equalled or exceeded

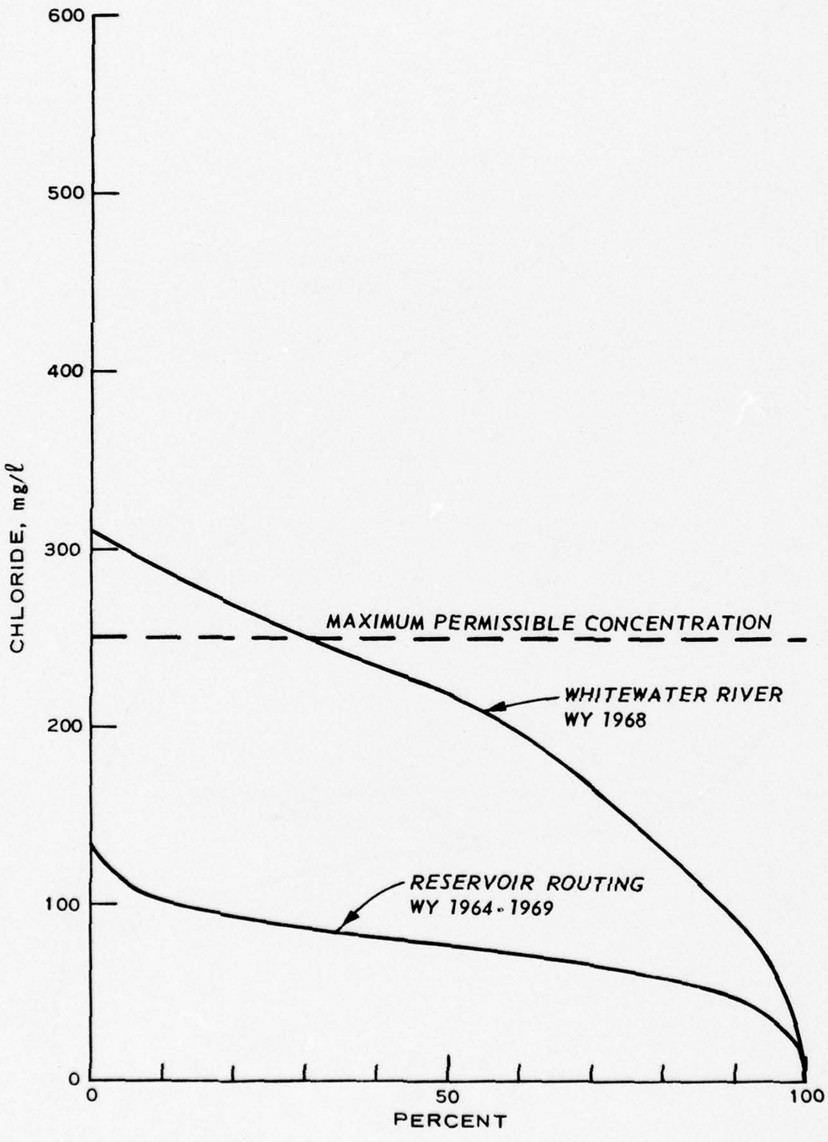

Figure 11. Comparison of predicted reservoir chloride concentrations with Whitewater River concentrations. Figure shows percent of time concentration was equalled or exceeded

downstream from the dam and would provide a buffer against the poor water quality occurring during base flow conditions.

Evaluation of Additional Data

Trace metals

16. Trace metal concentrations in the Whitewater River at Towanda are summarized in Table 7 along with the appropriate EPA criteria. Complete data are presented in Tables A1 and A2. Of the trace metals analyzed in the river, only cadmium and manganese occasionally exceeded EPA criteria for public water supply. Mean river concentrations of dissolved cadmium were 2 μg/ℓ during base flow and 7 μg/ℓ during elevated flow conditions. Mean dissolved manganese concentrations were 178 and 24 μg/ℓ during base and elevated flows, respectively. Concentrations of both of these constituents are expected to be lower in the reservoir than in the river.

17. Both total and dissolved forms of mercury frequently exceeded the EPA criteria of 0.05 μg/ℓ for the protection of aquatic life, but were less than the criteria of 2.0 μg/ℓ for domestic water supply.[2] The occurrence of mercury under both base and elevated flow conditions indicates a probable loading to the impoundment in excess of allowable limits for protection of aquatic life. Additional data should be obtained on mercury concentrations in the river and it would also be desirable to determine mercury concentrations in tissues of organisms inhabiting the river to ascertain the degree of accumulation within different trophic levels. If body burden concentrations in reservoir aquatic life exceed Food and Drug Administration limits, some aspects of the recreational potential of the project would be restricted.

Pesticides

18. Analysis of pesticide concentrations (Table 8) revealed concentrations below detection limits for all but 2,4-D and 2,4,5-T. These pesticides are not expected to cause problems in the proposed impoundment either for water supply or recreation purposes. River

concentrations of phenols, however, were consistently above the EPA water supply criterion of 1 μg/ℓ (Table 9). Phenolic compounds arise from oil refineries, livestock dips, degradation of pesticides, and natural sources. While phenol is rapidly degraded in natural water, some of these compounds, depending on the nature of the substituents on the benzene ring, are highly refractory and may exist for extended periods prior to degradation. Phenols are not removed efficiently by conventional water treatment and can be chlorinated during treatment to produce malodorous compounds.[2] Threshold odor levels can be as low as 2 μg/ℓ for 2-Chlorophenol.[5] Phenolic compounds can also cause tainting of fish flesh. Additional data should be obtained on phenol concentrations in the Whitewater River and in fish inhabiting the river to ascertain the degree of accumulation.

Nutrients and eutrophication

19. While an evaluation of the potential for algal blooms in the proposed reservoir is beyond the scope of this study, measured river concentrations of nitrogen and phosphorus (Table A4) are sufficient to support nuisance algal blooms. As the pool is not expected to exhibit strong stratification, wind action should maintain high turbidity. Algal populations are therefore expected to be light limited and blooms should occur only during periods of calm weather and lower turbidity. The occurrence of algal blooms is expected to be similar in frequency, magnitude, and duration to those of other shallow impoundments in the surrounding area.

Coliform bacteria

20. Fecal coliforms measured in the Whitewater River (Table 10) greatly exceeded the EPA criteria for primary contact recreation.[2] The EPA does not give a criterion for domestic water supply as coliform bacteria are easily controllable with conventional water supply treatment (chlorination). It is beyond the scope of this study to evaluate the extent of this problem in the reservoir, but the possibility exists that portions of the reservoir may not be useable for primary contact recreation following storm events. High levels of coliform bacteria will enter the reservoir during storm flows and will be distributed

throughout the pool according to the quantity and duration of the storm flow and the degree of mixing and dilution. Levels of these bacteria in the headwaters of the pool may exceed EPA criteria following storm events. The source of these bacteria will be difficult to control due the diffuse nature of the input. Comparison of fecal coliforms (FC) to fecal streptococci (FS) (FC/FS = 0.5) indicates the predominance of livestock or poultry wastes rather than human wastes.[6]

Estimation of treatment needs

21. Since predicted concentrations of Cl and SO_4 never exceeded EPA criteria, no specialized treatment for these parameters should be required. Predicted concentrations of TDS exceeded the 500-mg/ℓ level 37 percent of the time but in no case exceeded 660 mg/ℓ. The quality of the water for drinking is expected to be marginal with respect to TDS, but the expected concentrations do not justify the added expense of specialized treatment. Possible treatment processes for reducing TDS that might be considered during further planning, however, include partial demineralization or distillation. Both of these processes would also result in reduction of Cl, SO_4, Ca, and Mg.

22. Water supply problems associated with trace metals or pesticides are not expected although Mn concentrations in the hypolimnion may exceed EPA criteria. Consideration should be given to this potential problem in the design of the water supply withdrawal system. Concentrations of phenols may occasionally exceed EPA criteria. Chlorination of these compounds during treatment may produce malodorous compounds that are difficult to remove from finished waters.

Applicability of Results to Changes in Project Design

23. The effect of changes in conservation storage or yield on water-quality constituents was not addressed in this preliminary study. Increases in conservation storage may increase the likelihood of stratification, in which case a simple mass-balance routing would be inadequate for assessing water quality. Increased storage would also result in increased evaporation from the pool and consequently higher

concentrations of TDS, SO_4, and Cl. Under the conditions examined in this study, inflows are frequently smaller than losses due to evaporation and water-quality releases. Consequently, the pool elevation continually drops during drier periods of the year, and the occurrence of seasonal storm events is necessary to maintain conservation storage. The resultant increase in evaporative losses of water from an increase in storage may cause considerable changes in water level between dry and wet periods of the year. Increasing the water supply or water-quality releases may result in similar changes in water level fluctuation. Decreasing the conservation storage would lessen evaporative losses of water and may result in decreased water level fluctuations and, possibly, in improved water quality over the conditions evaluated in this study. The exact nature and extent of any such changes could be readily determined using the mass-balance routing model.

PART IV: CONCLUSIONS AND RECOMMENDATIONS

24. Conclusions and recommendations concerning impoundment water quality based upon this preliminary study are as follows:

- a. The results of the mass-balance routing indicate that expected concentrations of TDS in the proposed impoundment would occasionally exceed recommended limits. No problems are anticipated with Cl and SO_4 concentrations in the proposed impoundment. Analysis of additional data did not indicate serious water supply problems with respect to trace metals or pesticides. Based on these results, no specialized water treatment is warranted.
- b. Concentrations of mercury in the impoundment may exceed levels considered safe for the protection of aquatic life but are not expected to exceed criteria for domestic water supply. Additional sampling should be conducted to determine mercury loadings to the impoundment as well as the accumulation of mercury in tissues of organisms inhabiting the river.
- c. Concentrations of phenol may exceed acceptable levels and may cause tainting of fish flesh as well as taste and odor problems in finished water. Additional data should be obtained on the loading of phenol and possibly on the rate of decomposition.
- d. Occasional algal blooms are expected to occur in the impoundment and should be considered in designing the water supply withdrawal system. Algal blooms are expected to be similar in frequency, magnitude, and duration to those of surrounding lakes and reservoirs. Algal blooms should not affect the realization of recreational benefits.
- e. Fecal coliform bacteria are expected to exceed allowable levels following storm events and may preclude the use of portions of the reservoir for primary contact recreation during these periods.

REFERENCES

1. Leonard, R. B. et al., "Chemical Quality of the Streamflow of the Whitewater and West Branch Whitewater Rivers near Towanda, Kans., 1967-69," U. S. Geological Survey Report, 1969.

2. Environmental Protection Agency, "Quality Criteria for Water," EPA-440/9-76-023, Sep 1976, Washington, D.C.

3. U. S. Public Health Service, "Drinking Water Standards," U. S. Public Health Service Publication 956.

4. Bruvold, W. H. et al., "Consumer Assessment of Mineral Taste in Domestic Water," Journal of the American Water Works Association, Vol 61, 1969, p. 575.

5. Burttschell et al., "Chlorine Derivatives of Phenol Causing Taste and Odor," Journal of the American Water Works Association, Vol 51, 1959, p. 205.

6. Millipore Corp., "Biological Analysis of Water and Wastewater," Application Manual AM 302, 1973, Bedford, Massachusetts.

Table 1

Relationships Between Specific Conductance and Sulfates, Chlorides, and TDS During the Period 1962-1974

Parameter	n*	r**	Function
Sulfate, mg/ℓ	300	0.947	$0.0546\ C^{1.168}$†
Chloride, mg/ℓ	402	0.982	$0.00458\ C^{1.447}$
TDS, mg/ℓ	253	0.993	$0.811\ C^{0.968}$

* n = number of observations.

** r = coefficient of correlation.

† C = specific conductance, μmhos.

Table 2

Minimum Release Schedule Used in Mass-Balance Routing*

Month	Water Supply	Water Quality
Oct	3	22
Nov	3	19
Dec	3	19
Jan	3	19
Feb	3	15
Mar	3	19
Apr	3	22
May	3	22
Jun	3	28
Jul	3	35
Aug	3	32
Sep	3	24

* Units are in cubic feet per second.

Table 3

Annual Discharge of the Whitewater River at Towanda

Water Year	Total Discharge, cfs
1962	104,596
1963	38,713
1964	20,681
1965	181,618
1966	15,002
1967	61,038
1968	52,456
1969	165,194
1970	67,423
1971	16,975
1972	18,374
1973	124,521
1974	113,878
1975	103,987
1976	41,150
MEAN	75,040
MEDIAN	61,038

Table 4

Effect of Filling Conditions on Reservoir Concentrations of TDS, SO_4, and Cl Achieved During Initial Filling*

Parameter	Filling Condition		
	Storm Event	Median Year	Drought Period
TDS	125	464	1485
SO_4	27	125	453
Cl	10	74	315

* Concentrations are in micrograms per litre.

Table 5

Effect of Subsequent Median-Year Cycles on Reservoir Concentrations of TDS, SO_4, and Cl Achieved During Initial Filling*

	Filling Condition		
	Storm Event	Median Year	Drought Period
First Year			
TDS	347	437	623
SO_4	89	115	175
Cl	50	67	111
Second Year			
TDS	406	430**	479
SO_4	105	112**	128
Cl	61	65**	77

* Concentrations are in micrograms per litre.

** Concentrations selected as initial conditions for mass-balance routing.

Table 6

Percentage of Annual Discharge Above 2000 cfs

Water Year	Percent
1962	46.4
1963	50.4
1964	16.4
1965	69.8
1966	0.0
1967	69.7
1968	44.4
1969	59.9
1970	48.0
1971	0.0
1972	0.0
1973	65.0
1974	54.5
1975	53.9
1976	68.3
1964-69	59.5
1962-76	55.3

Table 7

Summary of Trace Metal Data for the Whitewater River at Towanda, Kansas, 1977*

Metal	Phase	Water Supply Criteria	Aquatic Life Criteria	Mean Concentration	Number of Samples	Range
As	Diss.	50	--	2.60	13	2-7
	Total			10.68	13	<1-34
Cd	Diss.	10	12**	5.80	13	1-13
	Total			10.00	13	<10-10
Cr	Diss.	50	100	1.45	13	<1-4
	Total			18.77	13	<10-40
Cu	Diss.	1000	Bioassay	8.20	1	2-19
	Total			21.60	1	1-40
Fe	Diss.	300	1000	125.40	13	20-280
	Total			14,923.00	13	1300-36,000
Pb	Diss.	50	Bioassay	7.00	13	1-22
	Total			100.00	13	<100-100
Mn	Diss.	50	--	65.10	13	<1-470
	Total			676.90	13	210-1500
Ni	Diss.	--	Bioassay	4.00	13	2-7
	Total			50.00	13	<50-50
Zn	Diss.	5000	Bioassay	20.20	13	4-50
	Total			76.90	13	30-160
Se	Diss.	10	Bioassay	1.08	13	<1-2
	Total			1.41	13	<1-4
Hg	Diss.	2.0	0.05	0.23	13	<0.1-0.6
	Total			0.20	12	<0.1-0.6

* Units are in micrograms per litre.

** For less sensitive aquatic life; 1.2 μg/ℓ for cladocerans and salmonid fishes.

Table 8

Summary of Pesticide Data for the Whitewater River at Towanda, Kansas, 1977*

Constituent	Water Supply Criteria	Aquatic Life Criteria	Mean Concentration	Number of Samples	Range
PCN	--	--	<0.01	7	--
Aldrin	--	0.003	<0.01	7	--
Lindane	4.0	0.01	<0.01	7	--
Chlordane	--	0.01	<0.10	7	--
DDD	--	--	<0.01	7	--
DDE	--	--	<0.01	7	--
DDT	--	0.001	<0.01	7	--
Dieldrin	--	0.003	<0.01	7	--
Endosulfan	--	0.003	<0.01	7	--
Endrin	0.2	0.004	<0.01	7	--
Ethion	--	--	<0.01	7	--
Toxaphene	5	0.005	<0.10	7	--
Heptachlor	--	0.001	<0.01	7	--
Heptachlor-Epoxide	--	--	<0.01	7	--
PCB	--	0.001	<0.10	7	--
Malathion	--	0.01	<0.01	7	--
Parathion	--	0.04	0.01	7	<0.01-0.01
Diazinon	--	--	0.03	7	<0.01-0.12
Methylparathion	--	--	<0.01	7	--
2,4-D	100	--	0.27	6	0.08-0.45
2,4,5-T	10	--	0.17	6	0.03-0.49
Silvex	--	--	<0.01	6	--
Trithion	--	--	<0.01	7	--
Methyltrithion	--	--	0.01	7	<0.01-0.01

* Units are in micrograms per litre.

Table 9

Phenol Concentrations in the Whitewater River at Towanda, Kansas, During Base Flow and Elevated Flow Conditions, 1977*

Flow Condition	Criterion**	Number of Samples	Mean	Range
Base	1	4	3.25	1-7
Elevated	1	9	4.44	2-14

* Units are in micrograms per litre.
** EPA criterion for domestic water supply.

Table 10

Summary of Microbiological Data for the Whitewater River at Towanda, Kansas, 1977*

Parameter	Criteria**	Geometric Mean	Range
Fecal coliforms	200	9,800	60-110,000
Immediate coliforms	--	41,500	750-460,000
Fecal streptococci	--	18,100	220-370,000

* Values are colonies per millilitres.
** The EPA criteria for primary contact recreation state that fecal coliform levels should not exceed a geometric mean of 200 per 100 ml nor should more than 10 percent of the samples taken during any 30-day period exceed 400 per 100 ml.

APPENDIX A: DATA COLLECTED

Table A1

Trace Metal Concentrations in the Whitewater River at Towanda, Kansas, During Base Flow Conditions*

Trace Metal	Phase	Date 21 Apr	19 May	27 Jun	21 Jul	4 Aug
As	Total	6	--	4	2	6
	Diss.	5	--	4	2	2
Cd	Total	10	<10	10	<10	<10
	Diss.	2	1	3	2	2
Cr	Total	<10	<10	10	10	10
	Diss.	< 1	< 1	< 1	< 1	< 1
Cu	Total	20	10	<10	10	1
	Diss.	5	1	3	2	2
Fe	Total	1300	1600	3200	1300	4600
	Diss.	140	20	30	20	30
Pb	Total	100	<100	100	<100	<100
	Diss.	4	8	5	9	5
Mn	Total	630	690	210	220	300
	Diss.	470	260	50	10	100
Ni	Total	<50	<50	<50	<50	<50
	Diss.	2	4	3	2	3
Zn	Total	30	30	70	50	30
	Diss.	10	20	10	4	8
Se	Total	1	1	2	1	2
	Diss.	1	1	2	1	1
Hg	Total	<0.1	0.1	<0.1	--	0.1
	Diss.	<0.1	0.3	<0.1	0.4	0.2

* Units are in micrograms per litre.

Table A2

Trace Metal Concentrations in the Whitewater River at Towanda, Kansas, Under Elevated Flow Conditions, 1977*

		Date and Time, hr											
		21 May		22 May			11 Aug			12 Aug			
Trace Metal	Phase	1500	1900	0855	1325	1700	1325	1610	2015	0820	1010	1230	1410
As	Total	9	6	13	22	3	34	--	--	15	--	<1	18
	Diss.	2	2	3	2	2	2	--	--	4	--	2	2
Cd	Total	<10	<10	<10	<10	<10	<10	--	--	<10	--	<10	<10
	Diss.	13	9	13	5	2	8	--	--	4	--	7	5
Cr	Total	20	40	20	30	0	36	--	--	16	--	16	16
	Diss.	<1	<1	<1	<1	<1	4	--	--	4	--	<1	<1
Cu	Total	30	40	30	30	20	40	--	--	20	--	10	20
	Diss.	5	11	15	5	5	12	--	--	11	--	19	12
Fe	Total	23000	36000	29000	25000	21000	24000	--	--	9200	--	7200	9200
	Diss.	280	110	160	130	160	150	--	--	160	--	120	140
Pb	Total	<100	100	<100	100	100	<100	--	--	<100	--	<100	<100
	Diss.	9	4	6	2	1	11	--	--	2	--	11	22
Mn	Total	790	1400	850	690	610	1500	--	--	530	--	530	540
	Diss.	120	40	8	<1	8	20	--	--	20	--	<1	<1
Ni	Total	<50	<50	<50	50	50	50	--	--	<50	--	<50	50
	Diss.	6	6	7	4	2	5	--	--	4	--	4	4
Zn	Total	90	160	100	110	70	130	--	--	50	--	50	60
	Diss.	20	20	20	30	50	20	--	--	20	--	30	20
Se	Total	1	1	1	<1	<1	<1	--	--	4	--	1	<1
	Diss.	<1	<1	<1	<1	<1	<1	--	--	<1	--	<1	<1
Hg	Total	0.1	0.2	0.6	<0.1	<0.1	0.4	--	--	0.2	--	0.2	0.2
	Diss.	0.2	0.3	0.4	0.2	0.6	0.1	--	--	<0.1	--	<0.1	0.2

* Units are in micrograms per litre.

Table A3

Concentrations of Pesticides in the Water and Sediment of the Whitewater River at Towanda, Kansas, 1977*

Constituent	Date and Time, hr								
	21 Apr	19 May	21 May		23 May	11 Aug		12 Aug	19 May
	1110	1300	1500	1900	1325	1610	2015	1010	Sediment
PCN	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	--
Aldrin	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.10
Lindane	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.10
Chlordane	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<1.00
DDD	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.10
DDE	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.10
DDT	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.10
Dieldrin	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.10
Endosulfan	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	--
Endrin	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.10
Ethion	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.10
Toxaphene	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<1.00
Heptachlor	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.10
Heptachlor Epoxide	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.10
PCB	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<1.00
Malathion	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<1.00
Parathion	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.10
Diazinon	<0.01	<0.01	0.12	<0.01	<0.01	<0.01	<0.01	<0.01	<0.10
Methyl Parathion	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.10
2,4-D	0.08	0.13	0.30	0.22	0.32	0.45	0.27	<0.01	<1.00
2,4,5-T	0.03	0.04	0.11	0.05	0.11	0.49	0.24	<0.01	<1.00
Silvex	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<1.00
Trithion	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.10
Methyltrithion	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.10

* Units are in micrograms per litre.

Table A4

General Water-Quality Data for the Whitewater River at Towanda, Kansas, 1977*

Parameter	21 Apr 1110	19 May 1300	21 May 1500	21 May 1900	22 May 0855	22 May 1325	22 May 1700	27 Jun 1115	21 Jul 1330	4 Aug 1340	11 Aug 1325	11 Aug 1610	11 Aug 2015	12 Aug 0820	12 Aug 1010	12 Aug 1230	12 Aug 1410
Discharge, cfs	15	10	1880	2260	1360	760	503	215	19	88	2790	3150	3310	1330	1020	769	662
Turbidity, JTU	20	30	600	700	480	700	460	65	30	80	1200	190	210	440	190	410	380
Conductivity, μmhos	2120	1820	445	419	285	293	320	815	1570	1530	310	210	210	258	305	380	408
Temperature, °C	16.0	22.5	18.0	17.5	17.0	18.0	18.0	23.0	28.0	24.0	21.0	21.0	20.0	20.0	20.0	21.0	21.5
Dissolved oxygen	7.2	9.2	4.6	4.1	6.3	6.4	8.0	7.0	14.4	8.6	4.4	4.6	5.8	6.0	6.1	6.2	6.3
Biochemical oxygen demand	0.9	3.5	3.4	5.2	--	--	--	--	6.4	5.5	5.0	4.4	4.7	7.2	8.4	8.4	7.9
Chemical oxygen demand	39	--	210	140	130	160	150	45	46	36	200	--	1	1	1	95	78
Alkalinity as $CaCO_3$	260	230	71	90	64	67	71	180	180	190	71	48	49	66	59	75	75
pH	7.7	7.9	7.2	7.4	7.4	7.4	7.3	7.9	8.3	7.8	7.5	7.4	7.6	7.6	7.6	7.7	7.7
HCO_3	270	280	86	110	78	82	86	220	220	230	86	58	60	80	72	91	91
CO_2	8.6	5.6	8.7	7.0	5.0	5.2	6.9	4.4	1.8	5.8	4.4	3.7	2.4	3.2	2.9	2.9	2.9
Ca + Mg hardness	830	--	160	150	100	110	120	350	560	540	110	--	--	100	--	140	150
Noncarbonate hardness	560	--	89	63	39	44	48	170	380	350	39	--	--	37	--	68	78
Total dissolved solids	1410	--	273	249	181	204	222	559	1010	1010	198	--	--	193	--	255	290
Dissolved Ca	240	--	46	45	30	33	35	100	150	150	32	--	--	29	--	41	43
" Mg	55	41	11	10	6.8	6.9	7.6	24	44	41	7.1	--	--	7.3	--	9.7	11
" Na	120	120	22	16	12	13	14	39	120	110	20	--	--	12	--	18	23
" K	6.6	7.1	6.6	7.5	6.4	6.3	6.3	6.7	5.6	4.7	5.1	4.6	--	8.6	--	8.6	9.7
" Cl	230	210	39	25	16	15	18	72	250	230	34	--	--	18	--	29	40
" F	0.5	0.4	0.4	0.3	0.4	0.4	0.4	0.3	0.3	0.3	0.4	--	--	0.4	--	0.3	0.4
" SO_4	480	330	71	76	42	46	49	150	270	290	40	--	--	38	--	67	71
" SiO_2	13	15	9.6	9.4	9.2	11	11	15	9.9	7.8	7.7	8.4	9.3	11	11	11	12
Total N	1.6	2.2	7.0	--	7.9	6.2	6.0	2.3	1.3	1.9	5.4	5.1	4.8	17	6.9	6.1	6.4
Total Kjedahl Nitrogen	1.2	1.9	5.2	--	6.0	4.1	3.7	1.2	1.3	1.6	4.3	3.7	34	15	4.6	3.7	4.1
$NO_2 + NO_3 - N$	0.38	0.31	1.8	1.7	1.9	2.1	2.3	1.1	0.01	0.25	1.1	1.4	1.4	2.2	2.3	2.4	2.3
Total P	0.13	0.35	1.0	0.31	0.99	0.87	0.79	0.28	0.15	0.19	1.4	0.75	0.76	0.82	0.89	0.89	0.87
Total Organic Carbon	7.3	7.1	42	43	39	34	31	8.8	10	9.7	63	--	--	34	--	29	26

* Units are in micrograms per litre except where indicated otherwise.

Table A5

Microbiological Data for the Whitewater River at Towanda, Kansas, 1977*

Date	Fecal Coliforms	Immediate Coliforms	Fecal Streptococci
21 Apr	64	11,000	300
19 May	60**	750	220
21 May	100,000	140,000	170,000
21 May	88,000	110,000	290,000
21 May	110,000	150,000	370,000**
27 Jun	1,900	4,100	2,000
21 Jul	18,000	13,000	440
4 Aug	2,300**	14,000	12,000
11 Aug	76,000	460,000**	160,000
11 Aug	40,000	300,000	150,000
12 Aug	93,000	320,000	220,000

* Units are colonies per 100 millilitres.

** Nonideal count.

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United States. Waterways Experiment Station, Vicksburg, Miss.
Preliminary evaluation of the water quality of proposed Towanda Lake, Kansas. Vicksburg, Miss. : Environmental Effects Laboratory, U. S. Army Engineer Waterways Experiment Station ; Springfield, Va. : available from National Technical Information Service, 1978.
28, [7], 6 p. : ill. ; 27 cm. (Miscellaneous paper - U. S. Army Engineer Waterways Experiment Station ; Y-78-3)
Prepared for U. S. Army Engineer District, Tulsa, Tulsa, Okla.
References: p. 28.

1. Evaluation. 2. Reservoirs. 3. Towanda Lake. 4. Water analysis. 5. Water quality. 6. Water supply. 7. Whitewater River. I. United States. Army. Corps of Engineers. Tulsa District. II. Series: United States. Waterways Experiment Station, Vicksburg, Miss. Miscellaneous paper ; Y-78-3.
TA7.W34m no.Y-78-3